Factors Affecting the Formation of Acrylamide in Coffee

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Abstract: Four types of green coffee beans (Robusta and Arabica) were roasted in a laboratory roaster and in an oven. The samples were analysed for acrylamide using liquid chromatography with UV detection. Significant difference in acrylamide content was observed in different coffee types. Robusta coffee beans, roasted to different degrees of browning contained more acrylamide than Arabica varieties. Roasting time and temperature had a great influence on the acrylamide formation in coffee beans. Coffee beans roasted for longer time had less acrylamide. Additionally, coffee beans roasted at higher temperatures contained less acrylamide compared to those roasted at lower temperatures.

Keywords: acrylamide; coffee; roasting; LC-UV

INTRODUCTION

Coffee is known worldwide for its flavour and harmonic taste. A long way of preparation of coffee beans since picking them from the coffee trees till roasting has an influence on the cupping quality and taste. What kind of coffee beans to choose and degree of roasting depends on consumer's taste and traditions. Many chemical reactions take part when coffee beans are roasted, the typical flavour and taste of coffee forms during this process, and the physical and chemical properties of the beans change. During roasting the volume of a bean increases, moisture content decreases. The aroma and taste compounds in coffee beans form when Maillard reactions (or non-enzymatic browning reactions), Streckers degradation, sugar degradation, minor lipid degradation reactions and interaction between intermediate decomposition products take place [1]. Recent studies showed that not only desirable compounds can be found in roasted coffee. Acrylamide (AA), a neurotoxic substance to both rodents and humans and probable carcinogen to humans [2] was detected in fried, deep-fried and baked foods [3, 4]. AA was also detected in commercially available coffee powder, instant coffee and brewed coffee [5]. Some studies showed that fresh or boiled foods contain no quantifiable levels of AA [6], it seems that roasting is the only probable way for AA formation in coffee beans. Some studied proved that AA is formed via the Maillard reactions [7]. It is a result of the reactions between free amino acids and reducing sugars [8]. The main precursors of AA seem to be asparagin and reducing sugars (glucose, fructose and etc.) [8, 9].

The aim of this study was to investigate the influence of coffee type, roasting conditions (time and temperature) and AA formation in coffee beans.

EXPERIMENTAL

Chemicals and solvents. *n*-Hexane (HPLC grade) and acetonitrile (HPLC grade) were obtained from LGC Promochem (Germany), formic acid 98–100% purity from Riedel-de Haen (Seelze, Germany). Water was obtained from purification system Simplicity 185 (Millipore, Billerica, MA, USA). Standard of acrylamide 99+% purity was obtained from MERCK-Schuchardt (Hohenbrunn, Germany).

Green coffee beans. Green coffee beans of Arabica (*Coffea arabica*) and Robusta (*Coffea canephora* Pierre) species were tested: Camerun Robusta (*C. canephora*, dry-processed), Santos Brasil, Columbian Excelso and Uganda Organico Biocoffee (*C. arabica*, wet-processed).

Roasting of coffee. The green coffee beans were either heated in a thermostated oven at 220–260°C for 5–15 min, or roasted in a small scale coffee roasting maschine (Wheeling, IL, USA).

Typical sample preparation and extraction for analysis of AA. 80 g of each type of green coffee beans were roasted in a coffee roaster. After roasting and cooling, coffee was ground immediately in a coffee grinder. 5.00 ± 0.01 g of coffee were taken to the 250 ml flask and fat was removed by extraction with 25 ml of *n*-hexane for 10 min. The procedure was performed in duplicate. The residues of *n*-hexane were removed under a stream of nitrogen.

For extraction of acrylamide 10 ml of water were added to 0.5000 ± 0.0001 g of dried coffee in a centrifuge tube. After the extraction for 30 s samples were centrifuged at 4000 U/min for 30 min and filtered through a filter. Then the supernatant was purified by SPE. The SPE cartridge was conditioned with 3 ml methanol and 3 ml water. As acrylamide is not retained the first 2 ml of the eluting solution were discarded and the rest collected. Until HPLC analysis the samples were stored at 4°C .

Concentration of acrylamide in each sample was calculated from a calibration curve. The limit of detection of 5 ng/ml was calculated using the software ValiData V1.01.

HPLC analysis of acrylamide. For HPLC analysis 10 µl of the purified extract were injected into an Agilent 1100 liquid chromatograph with a UV-detector, equipped with an Ion Pac ICE AS-1 (Dionex, Sunnyvale, CA, USA). The column was eluted isocratically with a flow of 0.400 ml/min using a mobile phase of 30% acetonitrile in 3mM aqueous formic acid. The effluent was monitored for its absorption at 202 nm.

The identification of AA was done by comparing the retention time with the standard substance. Additionally, for identification of AA LC-MS was used [10].

RESULTS AND DISCUSSION

Coffee beans roasted in a roaster. Green coffee beans were roasted in a laboratory roaster according to four roasting programmes. During roasting the temperature of all roasting programmes did not exceed 250°C. However, the time of roasting differed: 300 s (programme 4), 450 s (programme 6), 720 s (programme 8) and 870 s (programme 10). Cooling always took 300 s. After roasting samples were prepared fo HPLC analysis and the content of AA was measured. Data are shown in Figure 1.

Robusta (Camerun) was shown to have the highest amount of AA formed during roasting. Arabica coffee beans had lower amounts of AA compared to Robusta coffee beans. High quality Arabica coffee beans (Columbian Excelso and Uganda Organico Biocoffee) had a lower amount of AA compared to lower quality Arabica coffee beans (Santos Brasil).

Heated coffee beans in an oven. Green coffee beans of Robusta (Camerun) were heated on a glass dish in an oven at 220, 240 and 260°C for 5, 10 and 15 min. Before heating the glass dish was preheated for 10 min. After heating the dish with a sample was immediately put on ice for 15 min. Figure 2 shows the AA content in coffee beans roasted in the oven.

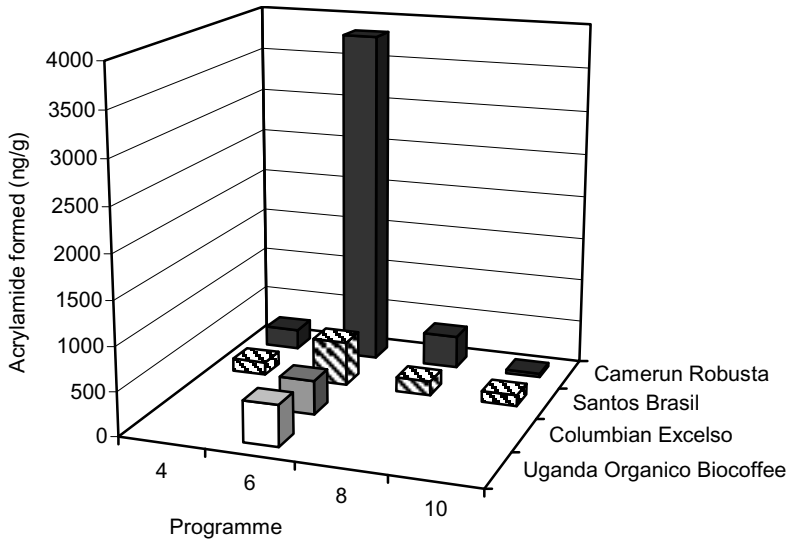

Figure 1. Acrylamide content (ng/g) in coffee beans roasted according to four roasting programmes

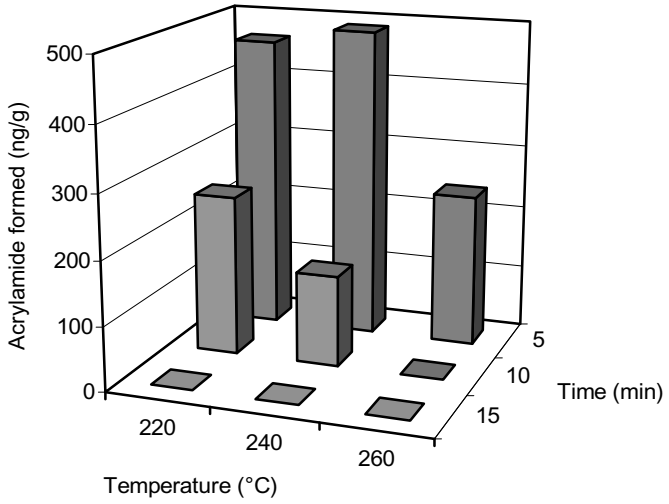

Figure 2. AA content in Robusta coffee beans heated in an oven at 220–260°C for 5–15 min

The highest concentration is detected in beans roasted at 240°C for 5 min. Beans roasted at 220 and 260°C for 5 min contained the highest amounts of AA. Roasting for longer times led to a reduction of the AA concentration. AA seems to form in highest concentrations during the first five minutes of roasting, but the amount of AA decreases with increasing the time of roasting. By using higher temperatures and a shorter time of roasting lower concentrations of AA were formed.

CONCLUSIONS

Our experiments showed a significant difference of AA in roasted coffee beans. Time of roasting and high temperatures had an influence on the formation of AA. AA concentration varied depending on roasting time/temperature value. The AA content varies depending on coffee type. This is in strong agreement with other studies [5].

Green coffee beans after processing contain usually not more than 12% of moisture [1]. The precursors – free amino acids and reducing sugars – vary depending on coffee spieces [1, 11], thus the AA concentration after roasting can differ. Reactions which can occur during roasting are very complex and more research is required to investigate the formation of AA.

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